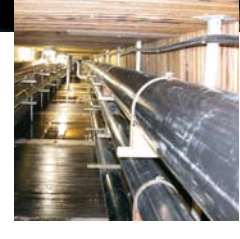

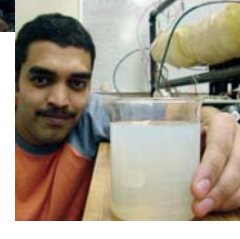

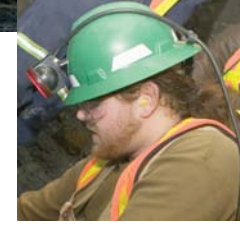

Institute of Northern Engineering
2006 Annual Report

College of Engineering & Mines
University of Alaska Fairbanks

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The **cover photo** of the McCall Glacier, in the Arctic National Wildlife Refuge in northeastern Alaska, is part of a comprehensive glacier-climate interaction study funded by NSF and led by Matt Nolan of the Institute of Northern Engineering Water & Environmental Research Center. This project includes installation, maintenance and data analysis for about a dozen automated weather stations on the glacier, as well as several continuously operating global positioning system (GPS) units, a mass balance stake network, and numerous survey transects for volume change. This project is a follow-up to research begun during the International Geophysical Year in 1957-58 by Richard Hubley. Dr. Nolan nicely captures the mood typical of the glacier, with bright sunshine up high and fog down low. This image is a repeat of a photo (opposite page) taken from exactly this same location in 1958 by Austin Post; careful comparison and analysis of the two has revealed valuable information on ice loss in this region. To learn more about this project, visit www.uaf.edu/water/faculty/nolan/glaciers/McCall/index.htm.

The 1958 photo was stitched together from six individual 6x6 cm negatives taken with a medium format camera to create a 180° view of the glacier. The cover photo was stitched together from nine individual shots taken using a 4 megapixel digital camera in portrait mode to create the same view.

Table of contents

Institute of Northern Engineering

Engineering solutions for the world's cold regions and beyond.

On behalf of the Institute of Northern Engineering, it is my pleasure to report on activities for the fiscal year 2005/06 and our plans for the coming year.

This is our second year since joining with the School of Mineral Engineering and the engineering departments from the College of Science, Engineering and Mathematics to form the College of Engineering & Mines. INE has a healthy history of nearly continuous growth since 1996, and this year was no different. While our state funding remained between $0.5 and $1.7M (million) over the past 10 years, our total revenues increased from $2.3M to $15.5M — an overall growth of nearly 600%. From July 2005 to June 2006, research expenditures rose from $11.8M to $15.5M, a single-year growth rate of 31%.

Highlights for fiscal year 2006 included the launch of the Alaska University Transportation Center (AUTC), a $15M endeavor under the leadership of Director Billy Connor. In addition, the Department of Civil and Environmental Engineering (CEE) worked to hire three new faculty with joint appointments in AUTC, and we welcome Drs. Jenny Liu, Xiong Zhang, and Ming Lee to our research enterprise.

INE also welcomes new EPSCoR faculty Kenan Harzibaba, who will address cold regions soils and liquifaction; WERC hydrologist Daqing Yang, who will take on a joint appointment between WERC and CEE; Dennis Filler, new CEE faculty and researcher in how climate change affects cold regions infrastructure, and how contaminants behave in freezing ground; Cathy Hanks, new faculty in Petroleum Engineering; and Jing Zhang, new faculty in Mechanical Engineering and researcher in materials properties. We also welcome INE research faculty Qing Liu, who will concentrate on vehicle traction and modeling issues. In the coming year, INE will continue recruiting and hiring research faculty to increase our research capacity.

Our plan for next year is based on four key elements. First, we will continue ***to expand the teaching/research model.*** In FY05/06, we secured $150,000 in initiative funding to start an INE joint appointment program. Through this program, any faculty in the college can apply for a ¼ time joint appointment with INE each semester. INE also secured $100,000 to expand its research faculty base. Research faculty, who are generally 75% funded by research grants, are able to respond to research opportunities quickly. Significant growth in INE depends on expanding this base. In the coming year, INE will look for new strategies to increase research opportunities for traditionally academic faculty.

INE will ***foster team building to recruit larger, longer term projects.*** To this end, we will coordinate major research opportunities and initiatives, encouraging above all the building of faculty teams that span campus units, multiple UA campuses, and other universities. INE will help such teams secure match dollars wherever possible. An important part of this goal is to collaborate with INE center directors to identify key growth areas, clarify where new resources should be invested, and determine how existing resources might be reassigned. As part of this process, INE has initiated a $50,000 travel grants funding program; the first awards were made in FY06/07. In addition, we will support ongoing research by underwriting two new technicians in 2006/07. These staff will serve as a direct-bill resource for projects.

INE will ***enrich research mentorship*** by developing strategies that pair senior and junior faculty in major research efforts, thereby reducing the start-up time necessary for new faculty to build strong research programs.

Finally, we will support a concentrated effort to ***raise international, national, and state awareness of INE's expert faculty and successful projects.*** INE engineers research solutions for the world's cold regions and beyond, and yet with a few exceptions, our expertise is a well-kept secret. This year, we are developing new strategies to increase our visibility in the state and throughout the circumpolar north. One excellent opportunity will be our participation in the International Polar Year (IPY), which will highlight research in the earth's polar regions. INE is hosting three new post docs and providing support to a range of new projects. In the past fiscal year, INE/WERC was nominated to lead UAF in hosting the 9th International Conference on Permafrost (NICOP; 29 June – 3 July, 2008) to coincide with IPY.

INE Mission Statement

The Institute of Northern Engineering engineers solutions for the world's cold regions and beyond.

INE conducts research in all areas of engineering, including, but not limited to: civil, computer, electrical, environmental, geological, materials, mechanical, mining, and petroleum engineering.

INE fosters opportunities for faculty, post-doctoral researchers, and students to tackle these engineering challenges.

INE focuses on basic and applied research and development, as well as research outreach.

INE promotes interdisciplinary and collaborative research and development.

INE supports partnerships with the natural and social sciences, education, business, geography, resource management, and law.

INE seeks to increase student involvement in research and development so that students at the University of Alaska graduate at the cutting edge of engineering and technology.

OVERVIEW

INE is home to approximately 60 faculty and staff researchers and provides research opportunities for roughly 80 graduate and undergraduate students annually. INE serves as a valuable contact to the Alaska business community, partnering with local businesses to convert basic research to applied technologies and disseminating new knowledge to professionals across the state. For FY06, INE faculty attracted over $12 million in external grants and support. Our ratio of external funding per dollar of university support is one of the highest among research units in the University of Alaska system.

Faculty conducting research through INE self-identify with one of our five centers based on their research interests and the expertise and facilities each center makes available. In addition to serving the College of Engineering & Mines faculty, INE supports independent (soft money) researchers, post doctoral positions, and expert research staff, as well as creating opportunities for graduate and undergraduate students to involve themselves in cutting-edge research. INE provides researchers with both administrative and technical support, through the services of:

- **The Business Office,** which works in partnership with the College of Engineering & Mines to provide financial services and support to faculty, staff and students. Staff assist these stakeholders in complying with complex federal, state, and university fiscal policies and procedures. They work in cooperation with the university community to support the broader missions of the College of Engineering & Mines and UAF.
- **The Publications & Proposals Office,** which offers extensive support in preparing, reviewing, and editing proposals, research articles and reports. Staff review and evaluate nearly 100 proposals each year, including analyzing budgets to assure compliance with complex federal, agency, and university regulations. Staff organize and disseminate research information, such as articles and reports, and public relations materials promoting INE and its centers. Staff also support research-related web pages, as well as maintain several databases.
- **INE technical research staff,** who offer expertise in data management and instrumentation development. They organize and maintain an institute-wide data processing, storage, and distribution system geared toward a wide range of research applications, including scientific data visualization and cartography, map projections and geospatial data formats. Staff also provide technical support for software and hardware related issues, and they maintain and repair research-related lab equipment.

The Arctic Energy Technology Development Laboratory (AETDL) promotes research, development, and deployment of energy technologies in Arctic regions by bringing together resources from the University of Alaska and the energy industry. AETDL is funded by the Arctic Energy Office of the DOE National Energy Technology Lab.

The Alaska University Transportation Center (AUTC) slogan is "Transportation safety, security and innovation in cold regions." AUTC strives to develop a robust transportation program capable of providing education, research, and outreach programs for infrastructure in cold regions. AUTC also seeks strong working relationships with AKDOT&PF, FHWA, FAA, USDOT, other universities (especially those in the Northwest United States) and other transportation agencies.

The Mineral Industry Research Laboratory (MIRL) conducts basic and applied research to aid in developing Alaska's mineral and energy resources. MIRL conducts studies concerning beneficiation and hydrometallurgy of Alaskan ores, geology, placer mining and gold recovery, mining-related problems in frozen ground, feasibility studies on mineral deposits, and environmental studies related to mining activities.

The Petroleum Development Laboratory (PDL) serves as a center of research leading to the development of technologies to extract, upgrade, manage, and commercialize Alaska's oil and gas resources. PDL research programs include basic and applied studies of oil displacement, reservoir properties of the Alaska fields, thermal recovery, miscible flooding, improved waterflooding, conventional natural gas and coalbed methane, gas hydrates, gas-to-liquids conversion and transportation, drilling, and production.

The Water & Environmental Research Center (WERC) emphasizes research on using Alaska's water resource environment. Faculty and students conduct research concerning inland and coastal, surface and subsurface water: its availability, quantity, quality, movement, and treatment. They study a range of issues, from how Arctic grayling pass through stream culverts, and how snowmelt influences available groundwater, to the physical, chemical, and biological processes of Arctic wetlands.

INE also hosts around 20 faculty who specialize in such areas as electrical, mechanical, and geological engineering and conduct their research directly through the Institute of Northern Engineering. Their projects, which range from robotics and nanotechnology to wireless communication systems and space physics, are shaped by defined state and national needs in combination with Alaska's unique environments.

College of Engineering & Mines

Institute of Northern Engineering

Arctic Energy Technology Development Laboratory (AETDL)

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Petroleum Development Laboratory (PDL)

Shirish Patil,
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Water & Environmental Research Center (WERC)

Douglas L. Kane,
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INE General Research (IGR)

About 20 faculty conduct research directly through INE in areas such as vehicle development, robotics, sensor networks, atmospheric studies, materials research, and engineering-relevant toxicology issues.

ARCTIC ENERGY TECHNOLOGY DEVELOPMENT LABORATORY

The Arctic Energy Technology Development Laboratory (AETDL) mission is to promote Research, Development, and Deployment (RD&D) of energy technologies in Arctic regions by bringing together resources from the University of Alaska Fairbanks and Alaska's energy industry. Its largest funding source is the US Department of Energy. AETDL identifies research needs with strong input from DOE, then calls for proposals from research organizations both inside and outside the university.

AETDL's original focus was twofold: to explore fossil energy resources by promoting RD&D of oil recovery, gas-to-liquids technology, and natural gas production and transportation; and to explore remote power issues by promoting RD&D of electric power in Arctic climates, including fossil, wind, geothermal, fuel cell, and small hydroelectric facilities.

To learn more, visit www.uaf.edu/aetdl

Faculty conducting research through AETDL:

Dennis Witmer, Ph.D.,
Director , Research Associate Professor, AETDL

Abjit Dandekar, Ph.D.
Associate Professor, Petroleum Engineering

Ragive Ganguli,Ph.D.,
Associate Professor, Mining Engineering

Chuen-sen Lin, Ph.D.,
Associate Professor, Mechanical Engineering

Debasmita Misra, Ph.D.,
Assistant Professor, Geological Engineering

Shirish Patil, Ph.D.,
Associate Professor, Petroleum Engineering

Daniel M. White, Ph.D.,
Professor, Civil & Environmental Engineering

Richard Wies, Ph.D.,
Associate Professor, Electrical & Computer Engineering

Tao Zhu, Ph.D.,
Associate Professor, Petroleum Engineering

Since September 2001, the **Arctic Energy Technology Development Laboratory (AETDL)** has initiated approximately 25 projects. A total of $13.5M (million) in Department of Energy funding has been committed to UAF, and $1.5M to federal partners (including National Laboratories and other federal agencies), for a total of $15M. This funding was matched by cost share of $5.7M, representing a total of about $20.7 million in funded research.

Current active projects are in oil and gas (heavy oil recovery, wax deposition in pipelines, and methane hydrates recovery), coal (low rank coal grinding), environmental impacts (tundra lakes study, CO^2 sequestration, water quality from coal seam natural gas production), and remote power issues (heat recovery from diesel engines, remote monitoring and control of rural utilities, and solid oxide fuel cells).

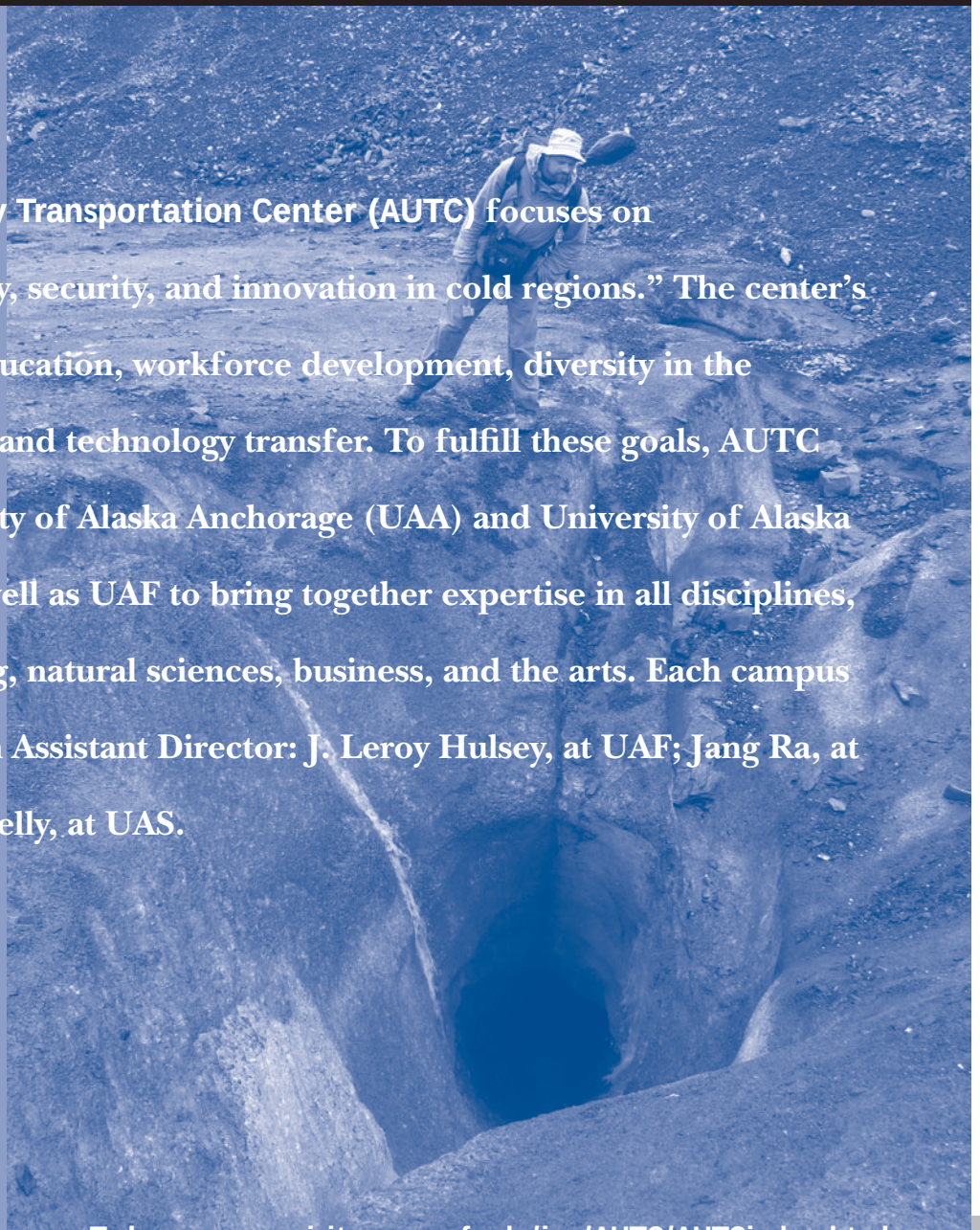
Initial AETDL funding and infrastructure have attracted other exciting projects. AETDL facilities include five fuel cell test stands, each with installed utilities, including compressed air, nitrogen, hydrogen (from either bottles or an electrolyzer), natural gas, propane, de-ionized water, liquid heat extraction, electrical service, internet access, and a separate air exhaust hood located directly over each test area. This lab was designed for long term testing of 5 kW fuel cells.

AETDL research staff are expert in verifying thermodynamic performance for small fuel cell systems. Verification requires careful measurement of fuel and coolant flows, electrical energy, and temperatures. By carefully calibrating test bench instrumentation, our staff can measure energy balances and account for all energy put into a system, and where that energy goes. This thermodynamic analysis is critical for evaluating long term viability of fuel cell systems suitable for large-scale commercial deployment. Our staff work with cutting-edge fuel cell companies to demonstrate the long term performance of their systems, including control system and balance-of-plant operating issues, stack performance and degradation, and ultimate failure mechanisms.

AETDL'S goal for the coming year is to continue evaluating those energy technologies most useful to Alaskans.

This year's highlight project is a partnership with Integrated Concepts & Research Corporation (ICRC) to evaluate the use of arctic-grade ultra-clean diesel fuel at low temperatures. The fuel has been used in transit buses serving the Fairbanks North Star Borough for the past two winters.

ALASKA UNIVERSITY TRANSPORTATION CENTER



The Alaska University Transportation Center (AUTC) focuses on "transportation safety, security, and innovation in cold regions." The center's primary goals are: education, workforce development, diversity in the workplace, research, and technology transfer. To fulfill these goals, AUTC will draw on University of Alaska Anchorage (UAA) and University of Alaska Southeast (UAS) as well as UAF to bring together expertise in all disciplines, including engineering, natural sciences, business, and the arts. Each campus effort is guided by an Assistant Director: J. Leroy Hulsey, at UAF; Jang Ra, at UAA; and Brendan Kelly, at UAS.

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To learn more, visit www.uaf.edu/ine/AUTC/AUTCindex.html

To reliably move goods and services, Alaska must successfully integrate all modes of transportation; our economic and social health depends on it. For instance, we can no longer settle for unreliable freight transport.

Nor can we accept the continually increasing costs of congestion, compromised safety, and poor system performance. When we throw in the challenges of building, operating and maintaining infrastructure in our cold regions, AUTC's focus becomes clear.

AUTC received a $16 million congressional grant to address these needs. This funding requires investment on Alaska's part: a dollar-for-dollar cost share and fearless innovation. AUTC is forging working relationships with the Alaska Department of Transportation & Public Facilities (AKDOT&PF), the US Department of Transportation, private transportation organizations, and other universities.

To meet our goals in developing expertise, this year AUTC Director Billy Connor, in cooperation with the College of Engineering & Mines, hired five new faculty specializing in geotechnical, structural, highway materials, and transportation operations. Assistant Director Ra is leading further recruitment efforts at UAA to fill a transportation materials position.

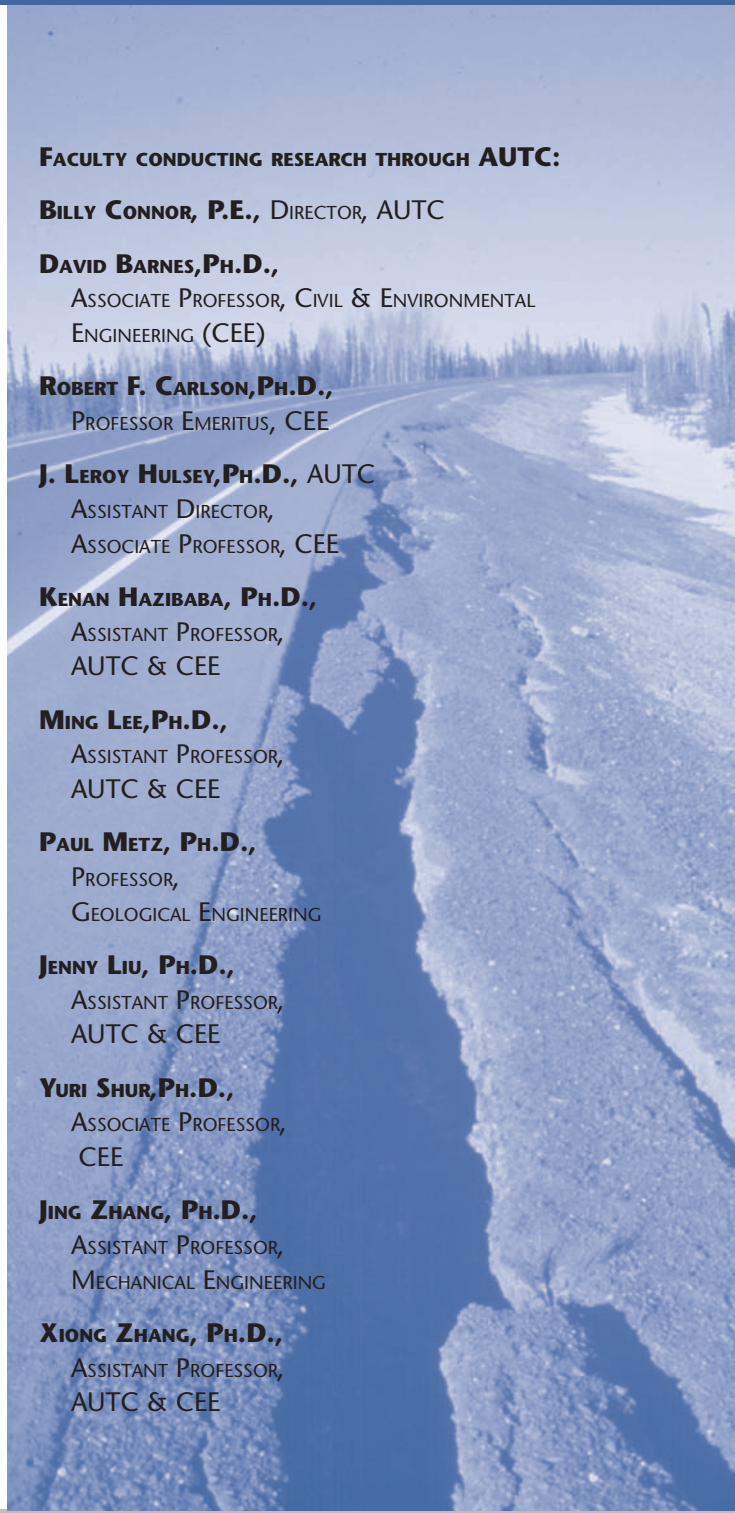
AUTC has numerous facilities available, including materials laboratories for asphalt, concrete, steel, and composite materials, as well as a cold room for simulating environmental variation in a lab setting. Our cooperation with local agencies and organizations also offers access to outdoor transportation facilities all over the state, allowing studies of infrastructure performance in climates ranging from the high Arctic to Alaska's southern coastal regions.

AUTC's goals for the coming year are to establish a governing board that will help us identify and prioritize short- and long-term research needs for both regional and national interests, to call for proposals and select research projects that address those needs, and to raise awareness of AUTC activities by publishing an annual report.

This year's highlight project: AUTC's David Barnes is working hand in hand with AKDOT&PF, the US Department of Agriculture, and the US Forest Service to develop an integrated plan for roadside vegetation control. Traditional methods of mowing have become too expensive to be effective in providing the sight distances necessary to avoid vehicle-animal collisions. Roughly 150 moose/car accidents occur in Alaska every year, at an estimated cost of around $1 million anually.

In many cases, mowing only attracts moose, because it creates an enticing smorgasbord of young willow sprouts. These partners are working together to explore vegetation control alternatives such as root disturbance, wet mowing (where herbicides are applied simultaneously with mechanical mowing) and other spray herbicide applications. This study will determine what mix of alternatives provides environmentally friendly, cost effective vegetation control for Alaska's roadsides.

In addition, it is providing valuable, hands-on research experience to two undergraduate Civil & Environmental Engineering students.



Faculty conducting research through AUTC:

Billy Connor, P.E., Director, AUTC

David Barnes, Ph.D.,
Associate Professor, Civil & Environmental Engineering (CEE)

Robert F. Carlson, Ph.D.,
Professor Emeritus, CEE

J. Leroy Hulsey, Ph.D., AUTC
Assistant Director,
Associate Professor, CEE

Kenan Hazibaba, Ph.D.,
Assistant Professor,
AUTC & CEE

Ming Lee, Ph.D.,
Assistant Professor,
AUTC & CEE

Paul Metz, Ph.D.,
Professor,
Geological Engineering

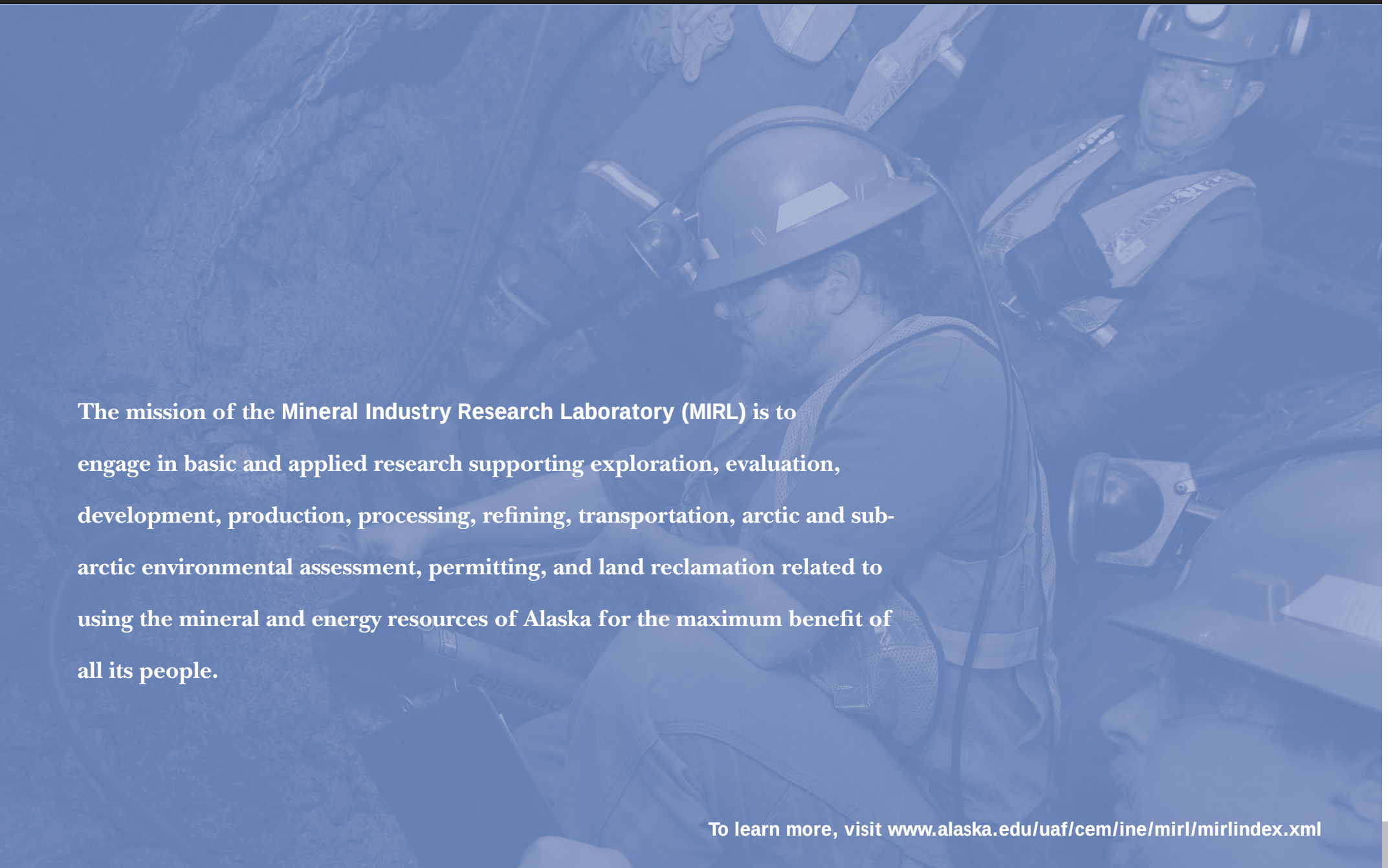
Jenny Liu, Ph.D.,
Assistant Professor,
AUTC & CEE

Yuri Shur, Ph.D.,
Associate Professor,
CEE

Jing Zhang, Ph.D.,
Assistant Professor,
Mechanical Engineering

Xiong Zhang, Ph.D.,
Assistant Professor,
AUTC & CEE

MINERAL INDUSTRY RESEARCH LABORATORY



The mission of the Mineral Industry Research Laboratory (MIRL) is to engage in basic and applied research supporting exploration, evaluation, development, production, processing, refining, transportation, arctic and sub-arctic environmental assessment, permitting, and land reclamation related to using the mineral and energy resources of Alaska for the maximum benefit of all its people.

To learn more, visit www.alaska.edu/uaf/cem/ine/mirl/mirlindex.xml

The **Mineral Industry Research Laboratory (MIRL)** was established by the 1963 Alaska Legislature to conduct basic and applied research to aid development of the state's mineral and energy resources. MIRL maintains labs in the Duckering Building and the MIRL Annex (which it shares with AETDL) on the UAF campus. MIRL facilities include sample collection and preparation equipment; analytical and optical equipment for rock, coal, and mineral analysis; and material testing equipment for rocks, aggregates, and soils.

MIRL has three primary goals for the coming year: 1) develop adjunct research faculty positions in mineral exploration and processing, mining operations, and environmental assessment and land reclamation; 2) seek out strategies to augment our existing state and federal funding with public sector and mineral industry support; 3) continue developing cooperative research projects with such schools as the Michigan Technological University and the University of Calgary, with a focus on the energy and transportation requirements of mineral industries in Alaska, Canada, and the contiguous United States.

Alaska contains over half the coal resources of the nation, and commercial quantities of at least thirteen of our nation's strategic mineral commodity requirements. Large conventional energy resources, including coal, petroleum, and natural gas, combined with some of the largest mineral deposits in the world provide Alaska with a unique opportunity to be a major mineral supplier to the United States and the Pacific Rim. In addition, Alaska has extremely large unconventional energy opportunities in the form of wind and geothermal resources. To facilitate producing, using, and exporting these resources, reliable bulk transportation systems including railroad and deepwater port facilities must be sited and constructed in arctic and sub-arctic environments.

This year's highlighted project: Through a federally funded program, "Rails to Resources," and in cooperation with the Alaska Department of Transportation and Public Facilities, the Alaska Railroad Corporation, the Yukon Territory Government, and numerous private sector contractors, MIRL is leading a project for site selection, design, and engineering economic analysis for extending the Alaska Railroad to the Canadian Railroad System, and ultimately to the contiguous United States.

Within the rail-link corridor mapped from Fairbanks to the Canadian border, there are nearly 600 mineral occurrences (sites or deposits where the presence of specific minerals has been identified and recorded) that could be served by the proposed bulk transportation system. There are another 2900 occurrences in the Yukon Territory and 4400 more in British Columbia. This project is the first step in making these resources more accessible to industry and, ultimately, the public. Preliminary results indicate that the economic benefits significantly exceed the $11-12 billion capital cost of the railroad extension.

FACULTY CONDUCTING RESEARCH THROUGH MIRL:

PAUL METZ, PH.D., DIRECTOR, MIRL AND PROFESSOR, GEOLOGICAL ENGINEERING

SUKUMAR BANDOPADHYAY, PH.D., PROFESSOR, MINING ENGINEERING

GANG CHEN, PH.D., PROFESSOR, MINING ENGINEERING

RAJIVE GANGULI, PH.D., ASSOCIATE PROFESSOR, MINING ENGINEERING

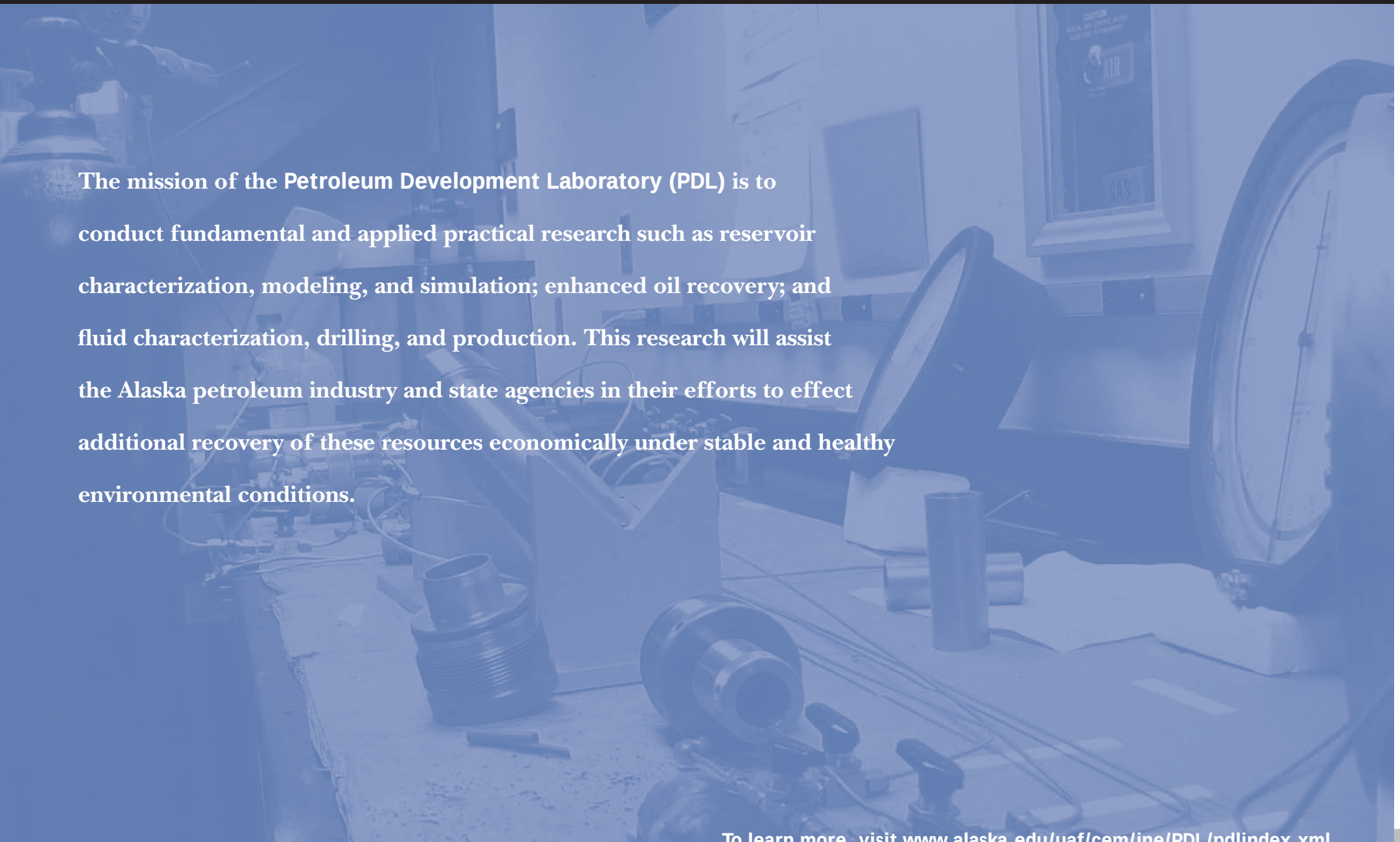
SCOTT HUANG, PH.D., PROFESSOR, GEOLOGICAL ENGINEERING

STEVE LIN, PH.D., PROFESSOR, HYDROMETALLURGY

DEBASMITA MISRA, PH.D., ASSISTANT PROFESSOR, GEOLOGICAL ENGINEERING

DAN WALSH, M.S., PROFESSOR, MINING EXTENSION

PETROLEUM DEVELOPMENT LABORATORY



The mission of the Petroleum Development Laboratory (PDL) is to conduct fundamental and applied practical research such as reservoir characterization, modeling, and simulation; enhanced oil recovery; and fluid characterization, drilling, and production. This research will assist the Alaska petroleum industry and state agencies in their efforts to effect additional recovery of these resources economically under stable and healthy environmental conditions.

To learn more, visit www.alaska.edu/uaf/cem/ine/PDL/pdlindex.xml

The **Petroleum Development Laboratory (PDL)** was established in 1984 to conduct energy-related research at the University of Alaska Fairbanks. Alaska's oil production currently accounts for about 20% of total US production. Alaska also holds over 25% of the entire nation's proven oil reserves, as well as massive reserves of natural gas, coal, and natural gas hydrates. PDL works to develop technology that helps make the best use of these resources and focuses on the special problems encountered in using Arctic petroleum reserves.

PDL projects attract funding from sources as diverse as the US Department of Energy and the Bureau of Indian Affairs. Recently, a significant amount of project support comes through the Arctic Energy Technology Development Laboratory (AETDL). All AETDL projects require at least one industry partner, and in response, PDL has established some strong collaborative ties with the petroleum industry both locally and nationally, and with government-linked research labs.

Faculty conducting research in PDL work to develop both conventional and unconventional energy resources. Current study areas include methane hydrates (resource evaluation and production), enhanced viscous oil recovery, carbon dioxide (CO^2) sequestration, coalbed methane, natural gas production from hydrates by CO^2 injection, Arctic cementing, gas-to-liquid (GTL) transportation through the Trans-Alaska Pipeline System (TAPS), microbial-enhanced oil recovery, and enhancing oil recovery by altering wettability.

PDL maintains specialized labs for both teaching and research. These include the Pressure-Volume-Temperature (PVT) Fluid Properties Lab, the Petrophysics Lab, Miscible Displacement Lab, Gas Hydrate Lab, GC/MS Analytical Lab, and a Reservoir Characterization and Modeling Lab.

PDL's goal for the coming year is to serve as the center for petroleum research and expertise in Alaska, and to make this expertise available through technology transfer and by providing a trained workforce to state and federal agencies, as well as industry.

This year's highlight project: PDL researcher Tao Zhu partnered with the University of Kansas and ConocoPhillips to win Department of Energy funding for a project that will study how oil from the Alaskan North Slope oil fields behaves in the pipeline; specifically, when and why wax forms in the pipeline, and how wax deposits might be prevented.

Faculty conducting research through PDL:

Shirish L. Patil, Ph.D., Director, PDL, Associate Professor, Petroleum Engineering Department (PETE)

Sukumar Bandopadhyay, Ph.D., Professor, Mining & Geological Engineering Department (MGE)

Godwin A. Chukwu, Ph.D., Professor, PETE

Abhijit Y. Dandekar, Ph.D., Associate Professor, PETE

Rajive Ganguli, Ph.D., Associate Professor, MGE

Santanu Khataniar, Ph.D., Professor, PETE

Nagendra Nagabhushana, Ph.D., Research Assistant Professor, PDL

Tao Zhu, Ph.D., Associate Professor, PETE

WATER & ENVIRONMENTAL RESEARCH CENTER

The mission of the Water & Environmental Research Center (WERC) is to perform basic and applied research related to water and environmental resources, to train graduate students at Master's and PhD levels, and to serve as an international research center committed to disseminating knowledge to the public. WERC researchers conduct fieldwork all over Alaska, from Kodiak to the North Slope, and throughout the world, from Iceland to the South Pole.

To learn more, visit www.alaska.edu/uaf/water/

Alaska offers many opportunities for scientists and engineers trained in water resources and related fields. WERC, established in 1965, is the only research group in the United States routinely producing graduates who specialize in permafrost hydrology. Around 20 students a year are supported by WERC projects; their studies are primarily in hydrology, civil engineering, or environmental engineering. WERC graduates go on to work in Alaska state agencies and are highly recruited to fill technical and management positions. Many graduates become certified as professional engineers and as professional hydrologists. WERC also employs undergraduate students in research positions every year. Our alumni regularly comment that their experience at WERC provided a wealth of technical skills and instilled a higher level of self-confidence, which they carried on into advanced study or into the work force.

Many of Alaska's resources are located in permafrost regions. When engineers design pipelines, drilling pads, roads, mines, runways, and buildings, they must design with partially or permanently frozen ground in mind. Hydrological considerations are less obvious but just as important. Most road failures (such as asphalt cracking and frost heave) occur thanks to thermal imbalance caused not by the road surface itself, but by water ponding along its shoulders. As another example, a critical issue in developing the Arctic National Wildlife Refuge is whether sufficient water resources exist for every day use, as well as for building the ice roads and pads so crucial to the oil industry.

WERC staff conduct field research under harsh conditions. They are experienced in analyzing and archiving large data sets and in computer analyses, including thermal and hydrologic modeling.

WERC facilities include cold rooms for controlled temperature experiments and equipment for measuring soil thermal and hydrologic properties.

WERC also houses the **Alaska Stable Isotope Facility (ASIF)**, which conducts high-tech research using stable isotope abundances as natural tracers. ASIF provides stable isotope ratio analyses to researchers throughout the world, in areas as diverse as paleoclimates, animal migrations, estimating past salmon runs, or sorting out food webs.

WERC's top goal for the coming year is to increase the number of graduate students involved in our research projects.

A WERC highlight project is a partnership with the Arctic Energy Technology Development Laboratory. Faculty are studying the hydrology and chemistry of North Slope lakes pumped for winter construction in the oil fields. In short, oil companies conduct their exploration in winter when they can drive across the tundra on ice roads and build on ice pads. Water to create these roads and pads is pumped from shallow lakes. This research is jointly supported by oil companies, state and federal agencies, and environmental conservation groups.

Faculty conducting research through WERC:

Douglas L. Kane, Ph.D., Director, WERC, Prof., Water Resources and Civil Engineering

David L. Barnes, Ph.D., Associate Professor, Civil & Environmental Engineering (CEE)

Svetlana Berezovskaya, Ph.D., Research Assistant Professor, WERC

Malcolm Ford, Research Assistant Professor, WERC

Ronald A. Johnson, Ph.D., Professor, Mechanical Engineering

Matthew Nolan, Ph.D., Research Associate Professor, WERC

Sarah Trainor, PhD., Research Assistant Professor, WERC

Robert A. Perkins, Ph.D., Associate Professor, CEE

Silke Schiewer, Ph.D., Associate Professor, CEE

Yuri Shur, Ph.D., Associate Professor, CEE

Horacio Toniolo, Ph.D., Assistant Professor, CEE

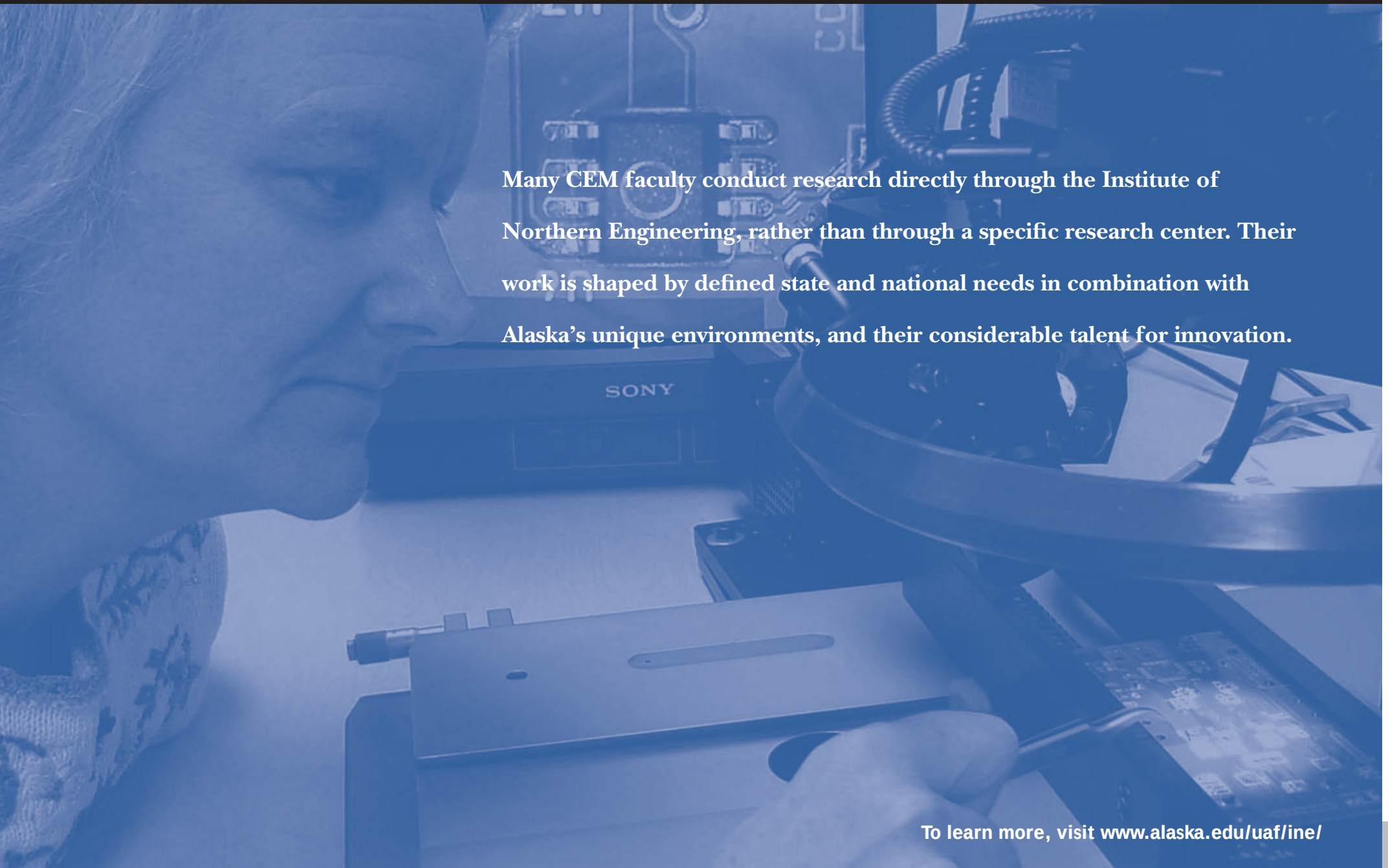
Daniel M. White, Ph.D., Professor, CEE

Mathew Wooller, Ph.D., Assistant Professor, Chemical Oceanography and Marine Biology

Daqing Yang, Ph.D., Associate Professor, WERC and CEE

Kenji Yoshikawa, Ph.D., Research Assistant Professor, WERC

INE GENERAL RESEARCH



Many CEM faculty conduct research directly through the Institute of Northern Engineering, rather than through a specific research center. Their work is shaped by defined state and national needs in combination with Alaska's unique environments, and their considerable talent for innovation.

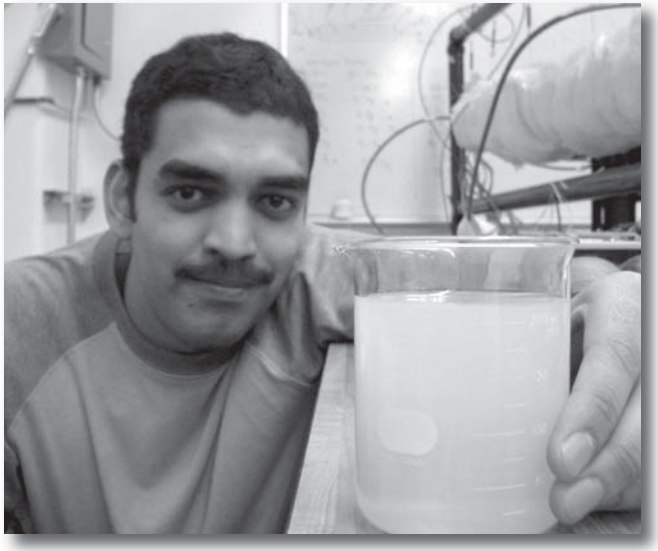
To learn more, visit www.alaska.edu/uaf/ine/

INE General Research (IGR) faculty study a wide range of issues; current research includes such projects as air quality (funded by EPA and Alaska Department of Health Services), wireless sensor networks (National Science Foundation), ultra-wide band communication (NASA), robotics (DOD), prototype vehicles designed for extreme terrain (Department of Defense), and materials research on the nano-scale (Office of Naval Research, National Institutes of Health, National Science Foundation), and electronic miniaturization (Murdock Foundation).

Although the majority of our research is conducted by faculty affiliated with the College of Engineering & Mines, INE welcomes all faculty engaged in engineering or related research. Facilities for IGR research include infrastructure and equipment maintained by both CEM and INE; these include labs and computer support, plus trained research and operations staff.

Goals for the coming year include expanding our technician base to support the growing amount of research produced by IGR faculty, fostering working groups to explore areas of research new to INE, and developing new strategies to make state-of-the-art equipment accessible to more researchers.

This year's highlight project: IGR researcher and mechanical engineer Rorik Peterson has figured out a way for the public to easily visualize ash clouds from any potentially active volcano in the North Pacific region. Peterson worked with colleagues at Unidata and in the Alaska Volcano Observatory to combine two programs (Unidata's Integrated Data Viewer, a Java-based software framework for analyzing and visualizing geoscience data; and Puff, a dispersion model that predicts airborne ash altitude, concentration, and fallout) to create a web site where users can view the projected paths of volcanic clouds. In addition to making this software more accessible to researchers and students all over the world, Peterson's project can be used for such applications as guiding aircraft around concentrations of airborne grit that can clog their engines. To learn more about this project, visit http://puff.images.alaska.edu/index.shtml.



Faculty conducting research through IGR:

Ed Bargar, Ph.D., Assistant Professor, Mechanical Engineering (ME)

Seta Bogosyan, Ph.D., Associate Professor, Electrical & Computer Engineering (ECE)

Boris Bracio, Ph.D., Assistant Professor, ECE

Eric Butcher, Ph.D., Associate Professor, ME

Cheng-fu Chen, Ph.D., Assistant Professor, ME

Debendra K. Das, Ph.D., Professor, ME

Dennis Filler, Ph.D, Assistant Professor, Civil & Environmental Engineering. (CEE)

Douglas J. Goering, Ph.D., Acting Dean of CEM, Professor, ME

Ronald A. Johnson, Ph.D., Professor, ME

Jonah Lee, Ph.D., Professor, ME

Chuen-sen Lin, Ph.D., Associate Professor, ME

Qing Liu, Ph.D, Research Assistant Professor, INE

Charles Mayer, Professor, ECE

Rorik Peterson, Ph.D., Assistant Professor, ME

Dejan Rascovic, Ph.D., Assistant Professor, ECE

Vikas Sonwalkar, Ph.D., Professor, ECE

Denise Thorsen, Ph.D., Assistant Professor, ECE

Richard Wies, Ph.D., Associate Professor, ECE

Jing Zhang, Assistant Professor, ME

Wei Zhou, Ph.D., Associate Professor, Geological Engineering

ACCOMPLISHMENTS 2006

We measure our success in terms of research produced and disseminated, students involved in research, and outreach to our surrounding communities. Highlights for 2005-2006 include:

Research, Dissemination And Growth In Our Research Centers

As of 31 June 2006, INE's total research portfolio was approximately $50M (million), with total fiscal year research expenditures of $15M.

This year INE, working with the Alaska State government, won US Department of Transportation funding to establish the Alaska University Transportation Center (AUTC). AUTC is one of only ten such centers mandated in a recent federal highway bill.

The Arctic Energy Technology Development Laboratory (AETDL) won $7M in new US Department of Energy (DOE) funding for FY06 and expects to receive DOE support for an additional five years.

INE won support for three International Polar Year (IPY) postdocs in FY06. These new researchers will focus on assessment of water resources, environmental changes in the hydrologic cycle of the circumpolar north, and past climate change in Alaska.

This year, WERC increased public access to their remote meteorological stations (for an example, see www.uaf.edu/water/projects/NorthSlope/e_kuparuk/sagwon/current.html), and these sites are becoming very popular. Alaska Weather, a regular show broadcast on Alaskan PBS stations, references WERC field sites on the North Slope. If a listener hears wind or temperature observations for such areas as Sagwon Hill and Green Cabin Lake, only WERC maintains monitoring instruments in these areas.

MIRL researcher Sukumar Bandopadhyay, working in partnership with Materials & Systems Research, Inc., won DOE funding to develop a "Novel, Efficient Solid-Oxide Fuel Cell Hybrid for Co-generation of Hydrogen and Electricity." The MIRL team will assess some factors affecting the electro-mechanical and thermo-mechanical integrity of an intermediate temperature Solid Oxide Fuel Cell. These factors include mechanical properties and creep due to high working temperatures, stress caused by thermal expansion mismatch, and stress due to temperature and chemical variations.

Students involved in Research

INE-administered research projects supported 79 graduate students, 17 undergraduates, and 6 post-doctoral positions in 2005/06. Students participating gained in both research and professional experience. Our Principal Investigators regularly sponsor student travel to professional conferences to present research

results, and INE students excel in this forum; at least five students took prizes for posters or paper presentations at various conferences this year. As one example, graduate student Thomas Oommen *(opposite page, left)* won the Outstanding Paper Award at the 2005 AGU meeting in San Francisco, for his work on "GIS Analysis of Marine Geophysical Signatures to Decipher Depositional Patterns of Platinum Placer in the Offshore Goodnews Bay Region, Alaska", a project headed by Geological Engineer Debasmita Misra (*opposite page, right).*

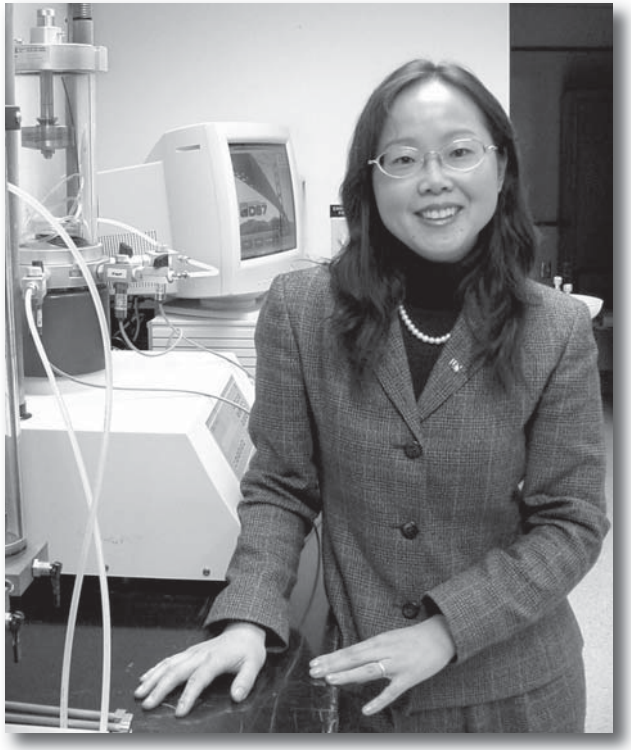
Community Engagement and Economic Development

Through a new partnership with the Cold Regions Research Engineering Laboratory (CRREL), INE faculty and staff gave educational tours in the local Permafrost Tunnel to more than 250 people, including elementary school students, visiting researchers, and local business people during 2005/06. This 360-foot-long research tunnel, originally excavated in the 1960s, runs through ice-rich permafrost. This underground laboratory is available for a variety of research programs, from studies of periglacial morphology to mining techniques for placer gold deposits.

Faculty of MIRL served as a source of information and support to the Alaskan mining industry, providing services, publications, and advice to approximately 100 people in FY06.

INE actively fostered partnerships with local research groups, including the Cold Climate Housing Research Center (CCHRC). On 21 July 2005, UAF researchers and administrators joined members of the local building community to celebrate groundbreaking for the Cold Climate Building and Infrastructure Research and Testing Facility (RTF). The center is a long-time supporter of INE research, sponsoring a multi-year project in indoor air quality and respiratory health headed by INE researcher Ron Johnson. The new RTF houses lab space for INE as a facility for testing cold weather structures, air quality research, and other experimental work aimed at meeting the needs of the cold climate housing industry.

INE/WERC researchers Matt Nolan and Peter Prokein helped the general public follow the Iditarod 2006 Sleddog Race online, in near real-time. The research team used two different technologies to show the race standings in 3D. The in-house INE project EarthSLOT (www.earthslot.org) provided the public with a view of the race and with the ability to create fly-through movies to visualize the Iditarod trail. Race standings were provided as a data layer for the popular Google Earth 3D virtual globe application. Nolan and Prokein's work was featured on the official Iditarod web site at www.iditarod.com, and thousands of daily visitors were able to use these services. This 3D race feature gained significant statewide news media coverage, as well as global coverage on the Internet as Iditarod enthusiasts world-wide spread the news of this service through their personal web sites and online journals.



GOALS 2007

We prepare for the future by actively engaging in research in the areas of transportation, energy, and the environment. In the coming year, INE will engage students in all aspects of research so that our graduates play a role in the next economic boom. In a longer view, we want to adequately position our graduates to compete for "legacy jobs", that is, jobs that will continue to benefit Alaska's economy well after the initial boom. INE, in accordance with UAF policy, has increased graduate salaries; we expect to attract higher numbers of more talented students.

Success in industry turns on identifying and investing in promising opportunities. We also seek to invest in a few new growth areas, along with our thriving traditional research areas. Ultimately, to become the national leader in northern engineering research, INE must invest its resources wisely.

Our goals for next year target four key areas:

- INE will expand our research faculty base by adding two new research faculty to INE. We will also work with CEM to expand the teaching/research model by increasing the number of joint appointments between the college and INE. Our goal is to add two new joint appointments, one quarter supported through INE and three quarters though CEM.
- INE will foster team building to recruit larger, longer term projects. To this end, we will develop a strategic plan to identify emerging opportunities in engineering and support our faculty in taking advantage of these opportunities.
- INE will target our travel grants program to support faculty engaged in launching large-scale projects. In addition, we will support new research by underwriting one new technician in 2006/07.
- INE will support a concentrated effort to raise international, national, and state awareness of INE's expert faculty and successful projects. We will increase our publications presence throughout the state, with a focus on highlighting our new research projects and our outreach activities. To this end, we will identify funding and an editorial board to launch a new research publication that will focus on engineering in the circumpolar north.

RESOURCES, FUNDING, & EXPENDITURES

Faculty in INE continue to successfully attract research funding. The ratio of external funding per dollar of university support (8:1) is one of the highest among research units in the University of Alaska system.

While the state funding INE receives has increased from $0.5 to $1.7M (million) over the past 10 years, our total revenues have grown from $2.3 to $15.5M — an overall growth rate of nearly 600%, with an average increase of 23% per year. Some of this growth reflects our 2004 combination of all UAF engineering units, which increased our number of grants and faculty overall. However, from July 2005 to June 2006, after all reorganization was complete, research expenditures grew from $11.8 to $15.5M, a growth rate of 31%. During this period, the general fund contribution to INE was only 11% of total expenditures.

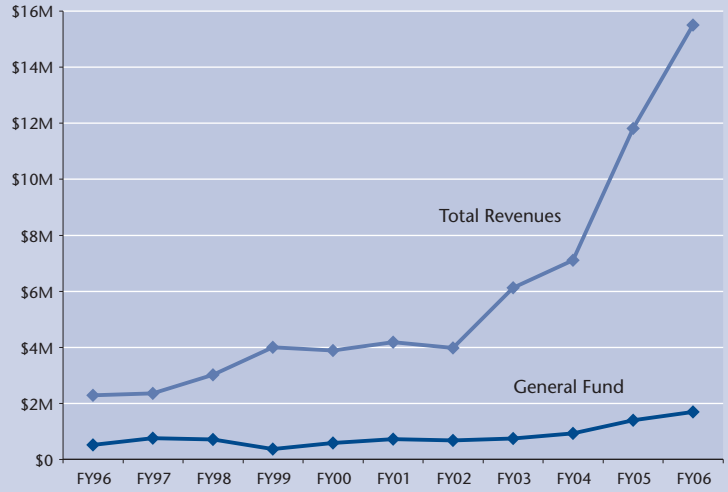
A full 83% of INE's external funds come from federal sources, both initiatives and grants from federal agencies such as the National Science Foundation, the Departments of Energy and Defense, National Aeronautics and Space Administration, and National Oceanic and Atmospheric Administration. A portion of this comes from federal initiatives, including funding to support the new Alaska University Transportation Center (AUTC) and the Arctic Energy Technology Development Laboratory (AETDL), as well as from sources such as the US Department of Interior's Minerals Management Service.

Approximately 10% of our external funding comes from Alaska state and local government sources, including the Department of Transportation & Public Facilities, Department of Fish & Game, and such groups as the Division of Health & Human Services.

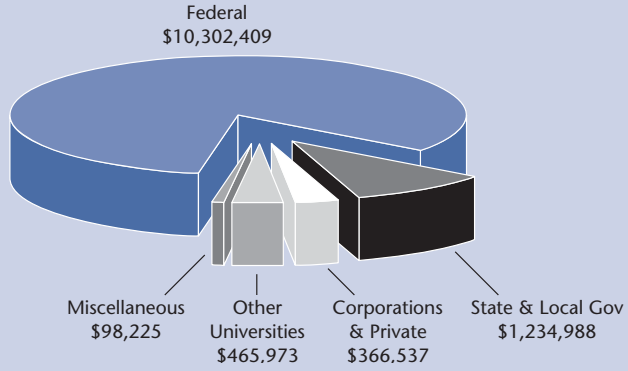
Another 3.7% represents our research collaborations with other universities. Our faculty participate in research consortiums such as the Center for General Aviation Research (lead by Embry Riddle) and the Automotive Research Consortium (lead by Michigan State University), as well as partnerships with organizations such as San Diego State University and the University of Wyoming.

Corporations and private business provide roughly 2.9% of our external funding. This includes research and analytical support performed for oil companies and such local businesses as Chena Hot Springs Resort. The balance of our funds (about .78%) comes from other sources, such as foundation grants.

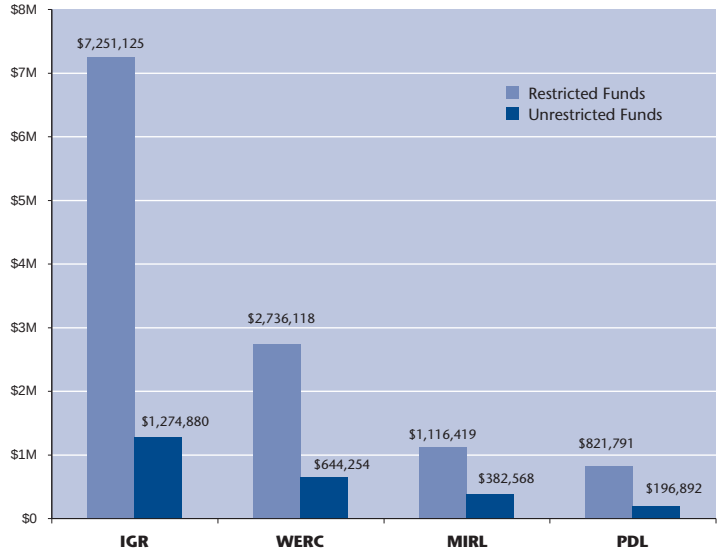
INE General Fund to Total Revenue



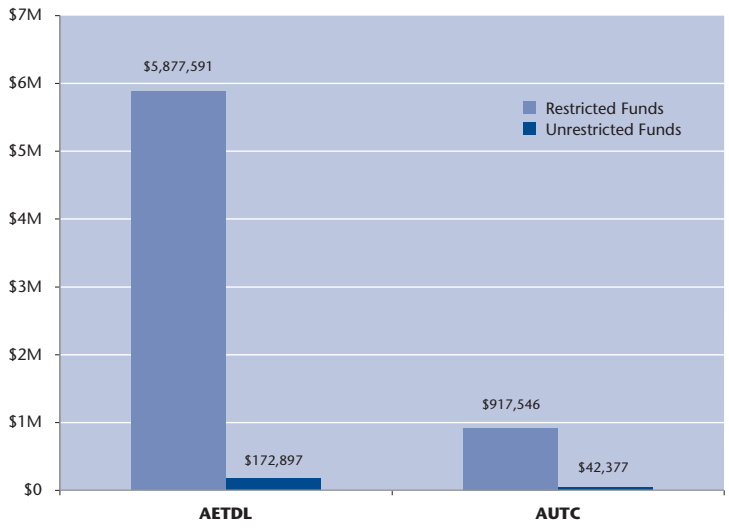
FY06 External Funds by Source



FY06 INE Expenditures by Lab/Center



FY06 Expenditures for AETDL and AUTC



Since 1996, INE has generated roughly $10M (million) in Facilities & Administrative costs for the University of Alaska. Approximately half has been returned to INE, which has devoted these funds to infrastructure and support of faculty research. Approximately $1M (of the $5M returned to INE) has been returned to individual faculty research accounts over the same ten-year period. Faculty use these funds for research-related activities, including travel, student support, project supplies, and, most importantly, for seed funding to jump start their newest and most daring projects.

INE total FY06 expenditures were about $15.5M. We have many highly productive faculty to thank for the bulk of this money – about $12.4M. In FY06, our people submitted 93 proposals (representing activity by approximately 43 faculty). By November 2006, 40 of these were funded, for a success rate of 42%.

Faculty self-identify with centers and labs based on their research interests and the expertise and facilities each center makes available. The graph to the left *(top)* shows a breakdown of both external (restricted) and general (unrestricted) funding by research centers and labs under the INE umbrella. Out of this $12.4M, Mineral Industry Research Laboratory (MIRL) projects represented 8.9%, while Petroleum Development Laboratory (PDL) projects represented 6.6%, and Water & Environmental Research Center projects accounted for about 21.9%. Research by faculty not affiliated with a lab or center (about 20 people) is reflected in the INE General Research (IGR) category, and accounted for 58% of restricted fund expenditures.

The bottom graph describes the activities of our two centers established by federal initiatives, the Alaska University Transportation Center (AUTC) and the Arctic Energy Technology Development Laboratory (AETDL).

In addition to attracting some new research funding, AETDL serves as a "clearing house" for focused federal initiatives by directing funds to other research centers, both within INE and externally, through collaborations with other centers, universities, and industry.

When an INE faculty member leads a project funded through AETDL, those expenditures appear under the faculty member's home center. This graph shows that AETDL has funded approximately $5.9M in research activity through various centers and labs within INE.

Expenditures in FY06 for the fledgling AUTC ($959,923) were focused on establishing infrastructure, developing a strategic plan, and identifying cost share opportunities.

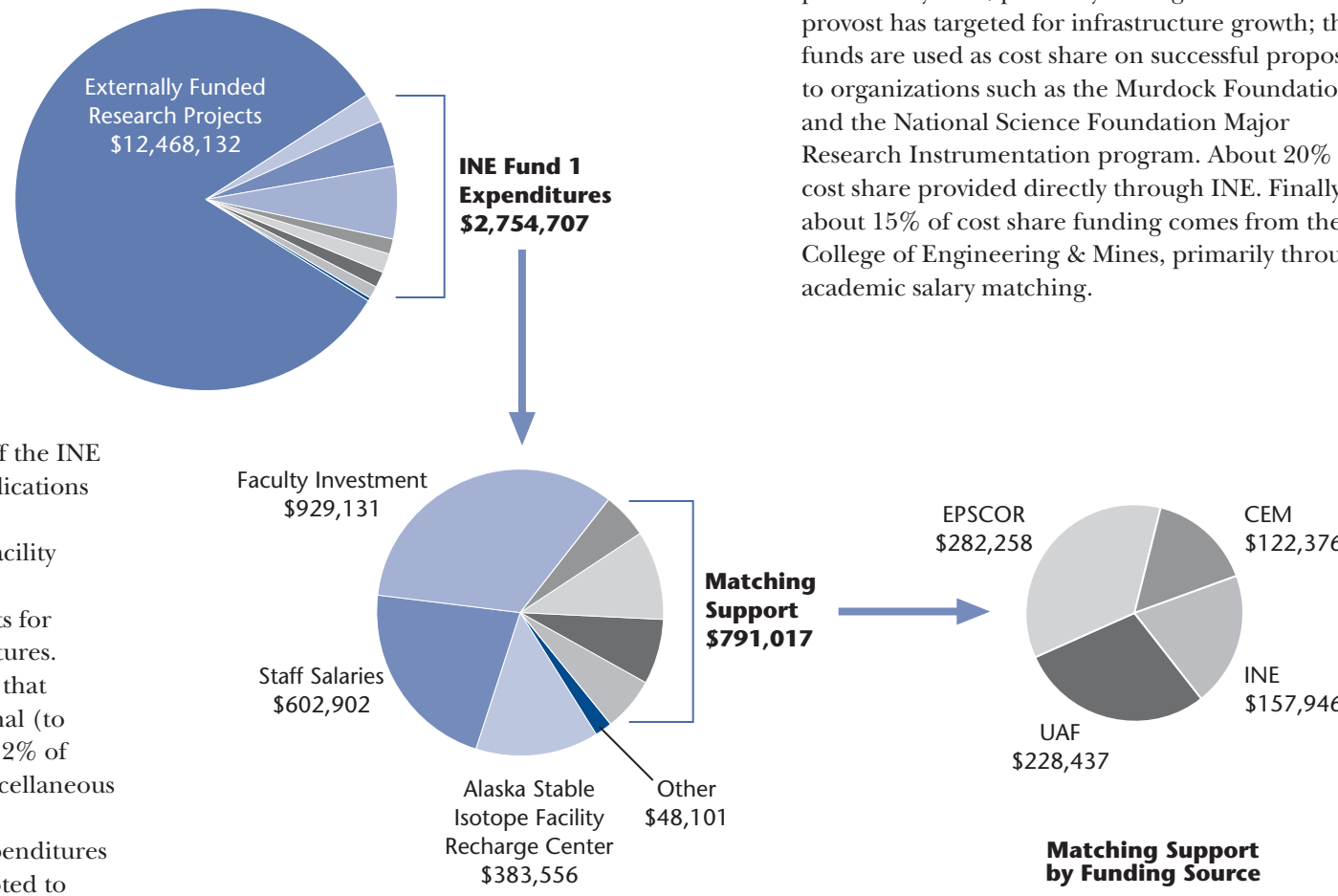
Unrestricted funds (sometimes called "Fund 1") represent support not committed to a specific research project. In FY06, INE had approximately $2.7M. Of this amount, 34% was invested in faculty, in the form of salary support, student travel, research equipment purchase and maintenance, project supplies, and most importantly, new faculty start-up funds.

About 20% of FY06 unrestricted funds supported INE staff, ranging from partial support of director salaries to research staff, as well as those who staff the INE Business Office and the Proposals & Publications Office.

Activity in the Alaska Stable Isotope Facility (ASIF), which is housed in the Water & Environmental Research Center, accounts for about 14% of FY06 unrestricted expenditures. ASIF is a self-supporting recharge center that provides analytical services to both internal (to UAF) and external researchers. Another 2% of these funds cover administrative and miscellaneous expenditures.

A key category in our unrestricted expenditures is matching funds, or funds that are devoted to mandatory cost sharing on research projects. About $791,017 (29%) of our Fund 1 expenditures fall into this category. Of this amount, 36% is provided by UA as a 1:1 match for the federally funded Alaska Experimental Program to Stimulate Competitive Research (Alaska EPSCoR). Another 29% is provided by UAF, primarily through funds the provost has targeted for infrastructure growth; these funds are used as cost share on successful proposals to organizations such as the Murdock Foundation and the National Science Foundation Major Research Instrumentation program. About 20% is cost share provided directly through INE. Finally, about 15% of cost share funding comes from the College of Engineering & Mines, primarily through academic salary matching.

FY06 Total INE Expenditures



Matching Support by Funding Source

INE owes its success to its outstanding faculty who, supported by our superbly qualified staff, engineer solutions for the world's cold regions and beyond.

Photo Credits

Cover Photo: see front inside cover. Pg 1: McCall Glacier, 1958; see note, front inside cover.

Pg 2: Daniel M. White, Director, INE. Photo by Kala Hansen, INE Publications & Proposals Office.

Pg 4: AETDL: prototype fuel cell in operation. Photo by Dennis Witmer. AUTC: UAF roundabout, at the junction of Tanana Loop and Thompson Drive. UAF photo by Todd Paris. MIRL: Ice coring. Photo by Kenji Yoshikawa. PDL: Petroleum Engineering grad student Shivkumar Patil works in a PDL lab. Photo by Hansen. WERC: Staff member Crane Johnson adjusts sensor instrumentation on a field Meteorological Station. Photo by Ken Irving.

Pg 5: All photos by Hansen.

Pg. 6: Fairbanks city bus, operating on ultra-clean diesel fuel. Photo courtesy of AETDL.

Pg 7: Tom Johnson and Jack Schmid, research engineers for AETDL, collect air quality data for the ultra-clean diesel fuel project. Photo by Dennis Witmer.

Pg 8: Profiles: J. Leroy Hulsey, photo by Silke Schiewer; Jang Ra, courtesy of University of Alaska Anchorage; Brendan Kelly, by Brendan Kelly. Right: Photo taken on the Matanuska Glacier, Alaska, showing a Moulin (a hole in the glacier caused by snowmelt water flow at the glacier's surface. Photo by Misha Kanevskiy, INE post-doctoral researcher.

Pg 9: Road damage in an Alaskan highway due to thawing permafrost under the roadway shoulder. Photo by Billy Connor.

Pg 10: MIRL researcher Gang Chen (standing, right) directs Geological Engineering student Andrew Schultz (center) in how to conduct a rock bolt pull test at the Delta Mine Training Center near Delta Junction. UAF photo by Todd Paris.

Pg 11: Mining students Aaron Debrah and Bissue Charles conduct grindability tests in the MIRL Mineral Processing Laboratory. Photo by Hansen.

Pg12: A work bench in a PDL lab.

Pg 13: Left, bottom: Petroleum Engineering Graduate students Nerallapally Sandeep Reddy, Shivkumar Patil, and Akshay Deo work in a PDL lab. Right column: Petroleum Engineering Graduate students Kaustubh D. Alurkar and Ganesh G. Morye build instrumentation in a PDL lab. Photos by Hansen.

Pg 14: WERC researcher Kenji Yoshikawa and his ship, the Hokimai, near Barrow (Elson Lagoon) during a sub-sea permafrost drilling project funded by the Japanese government and several Japanese foundations for environmental research. Yoshikawa built several wooden hand sleds, which he used to haul drilling equipment to his spring field site, where he measured sub-seafloor temperatures. Photo by Yoshikawa.

Pg 15: WERC researcher Silke Schiewer at the Red Dog Mine, Alaska, reviewing bioremediation fieldwork, part of a project funded by the US Department of the Interior. Photo courtesy of WERC.

Pg 16: IGR researcher Denise Thorsen examines circuits on a Pick & Place machine in the Electrical Analysis & Design Lab. This lab, which was jointly funded by the Defense Microelectronics Activity (DMEA) and a Murdock Foundation Grant, maintains high tech electronic equipment to support analysis and development of electronic systems for researchers throughout the University of Alaska Fairbanks. Photo by Hansen.

Pg 17: Left: Mechanical Engineering graduate student Devdatta Kulkarni shows off a nanofluid being tested for heat transfer and fluid dynamic performance. His work may lead to use of nanofluids in heating and coolant systems that will be more energy efficient and more tolerant of Alaska's extreme temperature changes. Column: A close-up of water flowing across saturated glacial flour near the Matanuska Glacier. Photo by Misha Kanevskiy.

Pg 18: Geological Engineering student Thomas Oommen (left) and his professor, Debasmita Misra, Geological Engineering, pose with Thomas' poster, which won the Outstanding Paper Award at the 2005 American Geophysical Union conference in San Francisco, CA. Photo courtesy of Geological Engineering.

Pg 19: Top: IGR researcher Wei Zhou, Geological Engineer, shows off her Geomaterials Lab. In the background is a soil triaxial testing machine with an automatic data collection unit. Bottom: INE instrumentation specialist Joel Bailey. Both photos by Hansen.

Pg 20: A scene from the MIRL Mineral Processing Laboratory; (clockwise, left to right) Brian McNulty (student), Rajive Ganguli (instructor), Dominick Orr (student), Dave Kitchens (student), Jacob Kalmbacher (student), Kris Catabay, Dan Walsh (instructor), Aaron Debrah (student), and Bissue Charles (student). Photo by Hansen.

Pg 21: Top: WERC researcher Svetlana Berezovskaya in the Brooks Range foothills, in the Upper Kuparuk River Watershed, an important research area for WERC. Berezovskaya conducted end-of-winter snow surveys, part of WERC's effort to fully describe the annual hydrologic cycle of the watershed. Bottom: INE researcher Daniel Fortier holds a handful of frazil ice. This ice formation occurred as a result of glacial hydraulic supercooling. In these circumstances, water flows through a deep channel in the glacier at subzero temperatures and under very high pressure; when the water begins to ascend to the surface, the pressure drops, and the super-cooled water very rapidly forms ice crystals. Photo by Fortier.

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